Section 3

Introduction to the Hyperion Instrument & Data Processing
Instrument & Data Processing

- Description of the Instrument
- Description of the Data the Instrument Produces
- Description of How the Instrument is Collects Data
- Description of the Level 1 Processing
HSA, HEA and CEA locations on the EO-1 nadir deck

Hyperion Spacecraft Accommodation

Hyperion Sensor Assembly (HSA)

Hyperion Electronics Assembly (HEA)

Cryocooler Electronics Assembly (CEA)
Hyperion on EO-1 Spacecraft

Hyperion Baffle

HYPERION

Hyperion CEA and HEA
Hyperion Subassemblies

Hyperion Electronics Assembly (HEA)
Contains the interface and control electronics for the instrument

Cryocooler Electronics Assembly (CEA)
Controls the cryocooler operations

Hyperion Sensor Assembly (HSA)
Hyperion Instrument – telescope, cryocooler, two grating spectrometers and supporting focal plane electronics, and cryocooler
Hyperion Hyperspectral Imager

- **Hyperion** is a push-broom imager with:
  - 196 10nm bands covering the spectrum from 430nm - 2400nm
  - 6% absolute radiometric accuracy
  - Image swath width of 7.6 km
  - GSD of 30.5 m at 705 km altitude
  - 16 day cycle orbit (8 day repeat for
    - selected locations)
  - 12-bit image data
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Hyperion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (L x W x H, cm)</td>
<td>39 x 75 x 66</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>49</td>
</tr>
<tr>
<td>Average Power (W)</td>
<td>51</td>
</tr>
<tr>
<td>Aperture (CM)</td>
<td>12</td>
</tr>
<tr>
<td>IFOV (mrad)</td>
<td>0.043</td>
</tr>
<tr>
<td>Crosstrack FOV (deg)</td>
<td>0.63</td>
</tr>
<tr>
<td>Wavelength Range (nm)</td>
<td>430 – 2400</td>
</tr>
<tr>
<td>Spectral Resolution (nm)</td>
<td>10</td>
</tr>
<tr>
<td>Number of Spectral Bands(cal)</td>
<td>196</td>
</tr>
<tr>
<td>Digitization</td>
<td>12</td>
</tr>
<tr>
<td>Frame Rate (Hz)</td>
<td>223.4</td>
</tr>
</tbody>
</table>
# Hyperion Performance - Highlight

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>On-orbit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPTICAL</strong></td>
<td></td>
</tr>
<tr>
<td>GSD (m)</td>
<td>30.5</td>
</tr>
<tr>
<td>Swath (km)</td>
<td>7.6</td>
</tr>
<tr>
<td>VNIR MTF @ 630nm</td>
<td>0.23-0.27</td>
</tr>
<tr>
<td>SWIR MTF @ 1650nm</td>
<td>0.28</td>
</tr>
<tr>
<td>Spatial Co-Reg: VNIR</td>
<td>.18 @ Pix #126</td>
</tr>
<tr>
<td>Spatial Co-Reg: SWIR</td>
<td>.21 @ Pix #131</td>
</tr>
<tr>
<td>Abs. Radiometry (1Sigma)</td>
<td>3.40%</td>
</tr>
<tr>
<td>VNIR SNR (550-700nm)</td>
<td>140-190</td>
</tr>
<tr>
<td>SWIR SNR (~1225nm)</td>
<td>96</td>
</tr>
<tr>
<td>SWIR SNR (~2125nm)</td>
<td>38</td>
</tr>
<tr>
<td><strong>RADIO-METRIC</strong></td>
<td></td>
</tr>
<tr>
<td>No. of Spectral Channels</td>
<td>198 Processed</td>
</tr>
<tr>
<td>VNIR (bands 8-57)</td>
<td>427-925 nm</td>
</tr>
<tr>
<td>VNIR Bandwidth (nm)</td>
<td>10.19-10.21</td>
</tr>
<tr>
<td>VNIR X-trk Spec. Error</td>
<td>2.2 nm</td>
</tr>
<tr>
<td>SWIR (bands 77-224)</td>
<td>912 - 2395 nm</td>
</tr>
<tr>
<td>SWIR Bandwidth (nm)</td>
<td>10.08-10.09</td>
</tr>
<tr>
<td>SWIR X-trk Spec. Error</td>
<td>0.58 nm</td>
</tr>
<tr>
<td><strong>SPECTRAL</strong></td>
<td></td>
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</table>
Hyperion Data

- Hyperion data cube – orientation
- Gray scale images of quick indication of data quality
- RGB color combinations
- Spectral examples
Hyperion Data Cube

- **Pushbroom configuration with common fore-optics 256 cross-track field-of-view locations**
  - Ground sample size is about 30.5 meter square
  - Corresponds to a 7.8 km swath width (7.6 km stated though entire swath is usable)

- **Current length of collect consistent with Landsat**
  - Typical image corresponds to a 185 km swath length (standard of 85 km being considered)
  - Correspond to 6072 frames of data. (30 second collect)
  - Frame rate of 223.4 Hz timed with spacecraft velocity
Hyperion Data Cube (continued)

- **Dichroic filter directs wavelength regimes to separate aft optics** (spectral – 242)
  - *Dichroic filter reflects VNIR and transmits SWIR wavelengths*
  - *Dispersive grating for VNIR comprise bands 1-70*
  - *Dispersive grating for SWIR comprise bands 71-242*
  - *Not all bands calibrated, but all bands are included in processed file*
    - *calibrated bands are indicated in data set*
Hyperion Data Cube

- **Hyperion Data Cube**
  - *X-swath width (pixels, field of view, cross-track)*
  - *Y-swath length (frames, line, along-track)*
  - *Z-spectral signature (bands, spectra)*

![Diagram of a Hyperion Data Cube]

- **X** field of view
  - 256 pixels

- **Y** time
  - 6072 frames

- **Z** spectral range
  - 242 bands
VNIR: Gray Scale Image

- **San Francisco, January 17, 2001**
  - Sample VNIR image of band 40 (753 nm)
  - Bands 1-70 (356 - 1058 nm)

- **Spectral Range**
  - Bands 8-57 (427 – 925 nm) calibrated
  - Selection based on signal level

- **CCD focal plane**
  - Absolute accuracy estimate 2.95%
  - Precision accuracy estimate 1.6%
  - Relative pixel-to-pixel accuracy 0.3 %
SWIR: Gray Scale Image

- San Francisco, January 17, 2001
  - Sample SWIR image of band 93 (1074 nm)
  - Bands 71-242 (852 –2577 nm)

- Spectral Range
  - Bands 77–224 (912-2394 nm) calibrated
  - Selection based on signal level

- HgCdTe focal plane
  - Absolute accuracy estimate 3.39%
  - Precision accuracy estimate 2.3%
  - Relative pixel-to-pixel accuracy 1.5%
  - SWIR calibrated temp -153.5 +/- 1 C.

Entire swath width

Subset of swath length

~700 lines shown

1074 nm (93)
Quick Indication of Image Quality

**VNIR**
- 753 nm (40)

**SWIR**
- 1074 nm (93)
San Francisco
January 17, 2001

To create RGB color images
Select 3 bands

San Francisco - January 17, 2001 Sample Spectrum

Wavelength (nm)

Radiance (W/m²/µm/sr)

Roof Top (a)
Water (c)
Yellow Flat (d)
Vegetation (f)

Hyperion visible color

Hyperion & ALI Data Users Workshop
Earth Observing-1

Roof Top (a)
Water (c)
Yellow Flat (d)
Vegetation (f)
San Francisco
January 17, 2001

641:580:509 nm
(29:23:16)

855:580:509 nm
(50:23:16)

2194:1649:1074 nm
(204:150:93)
Reflection of Solar Irradiance of a roof top, a reflective surface.
Some atmospheric features are indicated.
San Francisco
January 17, 2001

San Francisco - January 17, 2001 Sample Spectrum

Roof Top (a) Water (c) Yellow Flat (d) Vegetation (f)

Radiance (W/m²/um/sr)

Wavelength (nm)

San Francisco
January 17, 2001

Roof Top (a) Water (c) Yellow Flat (d) Vegetation (f)

Radiance (W/m²/um/sr)

Wavelength (nm)
Blue: Broad spectra of a highly reflective surface
Green: Characteristic of vegetation edge
Yellow: Minimal reflection in SWIR characteristic of the presence of water
Aqua Blue: Minimal reflection in SWIR characteristic of the presence of water, signal in VNIR indicative of scattering

Atmospheric Effects throughout
Three dimensional data set, how to visualize

- Gray scale spatial images, single band
- RGB spatial images, combinations of bands
- Spectral signature of a single pixel

Additional visualization

- Cross sectional plots (x-profile, y-profile)
- Expand color scales to emphasize upper/lower dynamic range

Advanced analysis

- Specifically selected RGB combinations
- Spectral profile processed with color map representation of a quantity
Profile of RGB bands across the Swath

- 855 nm
- 580 nm
- 509 nm

Expanded scale: Zooms in on the lower part of the VNIR dynamic range
World-wide range of spectral applications

- Forests
- Minerals
- Grasslands
- Glaciers
- Deserts
- Agriculture
- United States
- Argentina
- Antarctica
- Sahara
- Canada
- Australia
Hyperion Data Collection Event (DCE)

- **Suite consists of three dark calibration files, image file, and an internal calibration file**
  - **Dark calibration file**: cover closed, no internal illumination
  - **Image file**: typically 30 seconds (6702 lines), target within the middle 24 seconds
  - **Internal calibration file**: cover closed, internal calibration lamps on

- **Order of data collection**
  - **Instrument commanded to STANDBY mode** – focal plane electronics are powered
  - **Wait 10 minutes** to allow system to approach thermal equilibrium
  - **Collect pre-image dark calibration**
  - **Open cover - Collect image file**
  - **Close cover - Collect post-image dark calibration**
  - **Briefly turn on internal calibration lamp to collect in internal calibration file**
  - **Collect post-lamp collect**
Level 1 processing uses the pre and post image dark calibration file for dark subtracting the image file.

Single absolute calibration file used for all scenes.

Internal calibration file and post-lamp dark calibration file not used in Level 1 processing

Instrument modes (IDLE, STANDBY, IMAGING, SAFEHOLD)

- Normally in IDLE mode
- Transitions to STANDBY mode 10 minutes prior to image collect
Hyperion
Level 1 Data Processing

Supporting files produced along the way
EO1YYYYDDD_VVVVSSSSS_rs = fname

Step 0
Receive L0 data from GSFC

Step 1
Apply Smear correction to SWIR data
Flag pixels >4095: Fname.log

Step 2
Apply Echo removal to SWIR data
Fname.echo.log Ratio_rev#

Step 3
Interpolate for dark removal
Prepare for interpolated dark removal
Fname.smear.log
Fname.avg
Fname.avg.log

Step 4
Perform dark removal

Step 5
Apply released calibration:
Note: VNIR scaled by 40 and SWIR by 80
Fname.cal.log
HypGain_rev#

Step 6
Replace known bad pixels
Fname.fix.log Badpix#

Step 7
Review .L1_B image for quality assurance and attach center wavelength header
Fname.L1.qa Fname.L1.hdr

Step 8
Compile and write to tape the .L1_B and supporting data sets
Ship to GSFC for distribution

Level 1 DLT

Step 9
Ship to GSFC for distribution
To be discussed next
Metadata Files

Pre-Image Dark

Image Processing

Post-Image Dark
Residual Echo Evident

Mt Etna Day 203

Residual Echo is Clearly evident
Residual Echo & Smear

- **Echo and Smear artifacts are dependent on the analog signal**
  - *Echo and Smear algorithms are based on the digital number*
  - *The SWIR digital number will saturate before the analog signal saturates*

- **The SWIR may saturate on hot gas flares, fires, and volcano eruptions**
  - *When the SWIR digital number saturates, it is not possible to fully correct for the Smear and Echo artifact*

- **The fname.sat file was added to the level 1 processing and lists the saturated pixels as well as the not-properly corrected pixel**
Instrument & Data Processing

- Description of the Instrument
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- Description of the Level 1 Processing
Metadata Files

- **Examples of metadata files**
  - *Frame.echo.log*
  - *Frame.cal.log*
  - *Frame.fix.log*
Hyperion Metadata Files

- **General format: FNAME.echo.log**
  - **Procedure details:** name of procedure, when it was run, version of code
    - hypecho
  - **Arguments:** source file, output file, supporting files (if applicable)
    - fname.smear, fname.echo, ratio_revB.txt
  - **Details of each file:** file name including directory, dimensions, data type, byte order and pixel order
    - 256 pixels x 242 bands x 2000 frames, 16 bit integer, BIL
  - **Complementary information as applicable**
    - start band = 71 (correction for SWIR only, bands 71-242)
Hyperion Metadata Files

EO12001065_43CD43CC_r1_WGS_01.echo.log (part 1 of 1)

*****
hypecho
*****
HIP 1.1
Fri Nov 2 11:37:02 2001

----- Arguments -----  
  --source-file=EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CD43CC_r1_WGS_01.smear 
  --source-type=hyperion 
  --output-file=EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CD43CC_r1_WGS_01.echo 
  --output-type=hyperion 
  --start-band=71 
  --ratio-file=/dra2/calfiles/ratio_revB.txt 
  --verbose 

----- Source file -----  
  File name: EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CD43CC_r1_WGS_01.smear 
  Type: Hyperion 
  Dimensions: 256 pixels x 242 bands x 2000 frames 
  Data type: 16-bit integer 
  Byte order: big 
  Pixel order: BIL 

----- Output file -----  
  File name: EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CD43CC_r1_WGS_01.echo 
  Type: Hyperion 
  Dimensions: 256 pixels x 242 bands x 2000 frames 
  Data type: 16-bit integer 
  Byte order: big 
  Pixel order: BIL 
  Source: EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CD43CC_r1_WGS_01.smear 

----- Ratio file -----  
  Ratio file: /dra2/calfiles/ratio_revB.txt 
  Start band: 71 

********************
Hyperion Metadata Files

◆ General format: FNAME.cal.log

  – Procedure details: name of procedure, when it was run, version of code
    – cubecal

  – Arguments: source file, output file, supporting files and options (if applicable)
    – Note additional options: EX. calmax, calmin, VNIR & SWIR multipliers …

  – Details of each file: file name including directory, dimensions, data type, byte order and pixel order
    – 256 pixels x 242 bands x 2000 frames, 16 bit integer, BIL

  – Complementary information as applicable
    – Start band = 71 (correction for SWIR only, bands 71-242)
**Hyperion Metadata Files**

EO12001065_43CD43CC_r1_WGS_01.cal.log (part 1 of 3)

***** cubecal *****
HIP 1.1
Fri Nov  2 11:48:15 2001

----- Arguments -----  
--source-  
file=EO1670b/hyp/20010660219WGS/EO109208420010666111PP/EO12001065_43CD43CC_r1_WGS_01.echo  
--source-type=hyperion  
--output-  
file=EO1670b/hyp/20010660219WGS/EO109208420010666111PP/EO12001065_43CD43CC_r1_WGS_01.cal  
--output-type=hyperion  
--output-cubename=Hyperion .L1_A3  
--output-data=int16  
--cal-max=32767  
--darkcal-  
file=EO1670b/hyp/20010660219WGS/EO109208420010666111PP/EO12001065_43CA43C9_r1_WGS_01.avg  
--end-darkcal-  
file=EO1670b/hyp/20010660219WGS/EO109208420010666111PP/EO12001065_43CF43CE_r1_WGS_01.avg  
--labgain-file=/dra2/calfiles/HypGain_revB.dat  
--labgain-data=float32  
--labgain-byte=little  
--VNIR-multiplier=40  
--SWIR-multiplier=80  
--check-dead  
--cal-min=-32768  
--verbose

Continues ..........
Hyperion Metadata Files

EO12001065_43CD43CC_r1_WGS_01.cal.log (part 2 of 3)

----- Source file -----  
File name: EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CD43CC_r1_WGS_01.echo  
Type: Hyperion  
Dimensions: 256 pixels x 242 bands x 2000 frames  
Data type: 16-bit integer  
Byte order: big  
Pixel order: BIL

----- Output file -----  
File name: EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CD43CC_r1_WGS_01.cal  
Type: Hyperion  
Dimensions: 256 pixels x 242 bands x 2000 frames  
Data type: 16-bit integer  
Byte order: big  
Pixel order: BIL  
Source: EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CD43CC_r1_WGS_01.echo

----- Lab gain file -----  
File name: /dra2/calfiles/HypGain_revB.dat  
Type: Generic  
Dimensions: 256 pixels x 242 bands x 1 frames  
Data type: 32-bit floating point  
Byte order: little  
Pixel order: BIL

Continues .........
Hyperion Metadata Files

EO12001065_43CD43CC_r1_WGS_01.cal.log (part 3 of 3)

----- Dark cal file -----
File name: EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CA43C9_r1_WGS_01.avg
Type: Generic
Dimensions: 256 pixels x 242 bands x 1 frames
Data type: 16-bit integer
Byte order: big
Pixel order: BIL

----- End Dark cal file ----- 
File name: EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CF43CE_r1_WGS_01.avg
Type: Generic
Dimensions: 256 pixels x 242 bands x 1 frames
Data type: 16-bit integer
Byte order: big
Pixel order: BIL

----- Calibration options ----- 
VNIR Multiplier: 40
SWIR Multiplier: 80
Minimum: -32768
Maximum: 32767

----- Result ----- 

----- Summary ----- 
429017600 pixels calibrated
0 dead pixels (0%)
0 below min (0%)
0 above max (0%)

***********************
Hyperion Metadata Files

◆ General format: FNAME.fix.log

- Procedure details: name of procedure, when it was run, version of code
  - cubefix

- Arguments: source file, output file, supporting files and options (if applicable)
  - Note additional options: badpix3

- Details of each file: file name including directory, dimensions, data type, byte order and pixel order
  - List of bad pixels listed in badpix3

- Complementary information as applicable
  - Approach used to replace bad pixels
**** cubefix ****
HIP 1.1
Fri Nov 2 11:58:01 2001

----- Arguments -----  
--source-file=EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CD43CC_r1_WGS_01.cal  
--source-type=hyperion  
--output-file=EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CD43CC_r1_WGS_01.L1_A3  
--output-type=hyperion  
--output-data=int16  
--bad-file=/dra2/calfiles/badpix3  
--verbose

----- Source file -----  
File name: EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CD43CC_r1_WGS_01.cal  
Type: Hyperion  
Dimensions: 256 pixels x 242 bands x 2000 frames  
Data type: 16-bit integer  
Byte order: big  
Pixel order: BIL

----- Output file -----  
File name: EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CD43CC_r1_WGS_01.L1_A3  
Type: Hyperion  
Dimensions: 256 pixels x 242 bands x 2000 frames  
Data type: 16-bit integer  
Byte order: big  
Pixel order: BIL  
Source: EO1670b/hyp/20010660219WGS/EO10920842001066111PP/EO12001065_43CD43CC_r1_WGS_01.cal
Hyperion Metadata Files

EO12001065_43CD43CC_r1_WGS_01.fix.log (part 2 of 3)

----- Bad pixels file -----
File name: /dra2/calfiles/badpix3

----- Bad pixels (band, sample)-----
1, 1
... (edited file)
35, 1
61, 93
72, 95
94, 93
99, 92
116, 138
119, 240
120, 240
165, 248
168, 256
169, 23
190, 113
200, 8
201, 8
203, 115

continues ..........
Hyperion Metadata Files

EO12001065_43CD43CC_r1_WGS_01.fix.log (part 3 of 3)

----- Result ----- 
(1, 1): 100% of 2  
... ... ...  (edited file) 
(35, 1): 100% of 2  
(61, 93): 50% of 92 and 94  
(72, 95): 50% of 94 and 96  
(94, 93): 50% of 92 and 94  
(99, 92): 50% of 91 and 93  
(116, 138): 50% of 137 and 139  
(119, 240): 50% of 239 and 241  
(120, 240): 50% of 239 and 241  
(165, 248): 50% of 247 and 249  
(168, 256): 100% of 255  
(169, 23): 50% of 22 and 24  
(190, 113): 50% of 112 and 114  
(200, 8): 50% of 7 and 9  
(201, 8): 50% of 7 and 9  
(203, 115): 50% of 114 and 116  

----- Summary ----- 
339325 pixels fixed out of 429017600 (0.0790935%)  

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